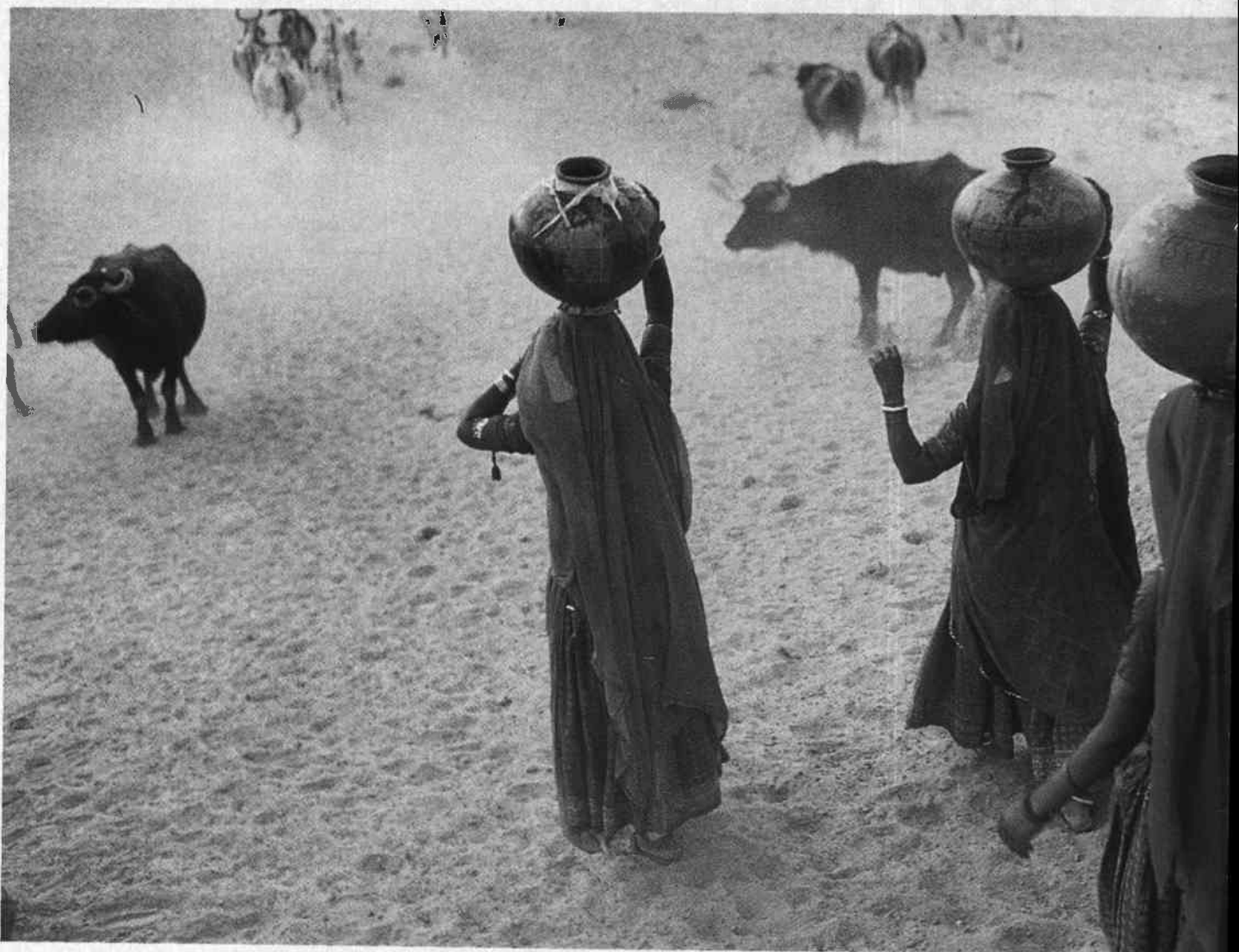


Population, Poverty and the Local Environment

*As forests and rivers recede, a child's labor
can become more valuable to parents, spurring
a vicious cycle that traps families in poverty*

by Partha S. Dasgupta



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ing food. Being identical, the bowls present a twofold symmetry. Yet the dog arbitrarily picks one bowl. Unable to accept that the symmetry is entirely lost, Nambu discovered that the dog, in effect, cannot make up her mind and constantly switches from one bowl to the other. By the laws of quantum physics, the oscillation comes to life as a new particle, a boson.

Nambu points out that others, such as Bardeen, Philip W. Anderson, then at Bell Laboratories, and Gerald Rickayzen, then at the University of Illinois, also saw that a superconductor should have such a particle. It was Nambu, however, who detailed the circumstances and significance of its birth and realized that the pion, as well, was born in like manner (by breaking the chiral, or left-right, symmetry of quarks). While he searched for more of its siblings in nature, Nambu circulated his findings in a preprint.

Jeffrey Goldstone, then a postdoctoral fellow at CERN, the European laboratory for particle physics, realized the import of this work and soon published a simpler derivation, noting that the result was general. Thereafter the new particle was dubbed the Goldstone boson. ("At the very least, it should

be called the Nambu-Goldstone boson," Goldstone comments.) When Nambu finally published his calculations in 1960, his paper also showed how the initially massless particle mixes with a magnetic field in a superconductor to become heavy. Recognized by Anderson, Peter Higgs, then at the Institute for Advanced Study, and others as a general phenomenon, it later became the Higgs mechanism of the Standard Model of particle physics.

In the years that followed, Nambu studied the dynamics of quarks, suggesting they were held together by gluons carrying a color quantum number to and fro. "He did this in 1965, while the rest of us were floundering about," Gell-Mann says. (Nambu, however, believed the quarks to be observable and assigned them integer electrical charges, an error that Gell-Mann and others corrected.) In 1970, perusing a complex mathematical formula on particle interactions, Nambu saw that it described strings. In the 1980s his "string action" became the backbone of string theory.

"He has an amazing power of coming up with pictures," says Peter G. O. Freund, a colleague at Chicago. While working with Nambu, I noticed that he

would look at a problem from several different, yet simultaneous, points of view. It was as if instead of one mind's eye he had at least two, giving him stereoscopic vision into physical systems. Where anyone else saw a flat expanse of meaningless dots, he could perceive vivid, three-dimensional forms leaping out.

Over time, Nambu became known as a seer, albeit a shy one. "I can think of no one who gives such good advice," Witten says. Pierre M. Ramond of the University of Florida observes that the directions of particle physics were often predicted by Nambu's papers—encrypted in the footnotes.

These days Nambu puzzles over how quarks acquire their diverse masses. He suggests they might come from historical accident, such as the quarks being born at different stages of the early universe. His thoughts have also turned to biology and to an old bane, entropy. Nambu calculates that virus-size particles, when placed in a cusp-shaped container, seem to violate gravity and entropy. Perhaps they conceal a clue as to how life-forms defy entropy and become ever more organized. Prophecy or quixotic fancy? Ten years from now, we might know. —*Madhusree Mukerjee*

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As with politics, we all have widely differing opinions about population. Some would point to population growth as the cause of poverty and environmental degradation. Others would permute the elements of this causal chain, arguing, for example, that poverty is the cause rather than the consequence of increasing numbers. Yet even when studying the semiarid regions of sub-Saharan Africa and the Indian subcontinent, economists have typically not regarded poverty, population growth and the local environment as interconnected. Inquiry into each factor has in large measure gone along its own narrow route, with discussion of their interactions dominated by popular writings—which, although often illuminating, are in the main descriptive and not analytical.

Over the past several years, though, a few investigators have studied the relations between these ingredients more closely. Our approach fuses theoretical modeling with empirical findings drawn

from a number of disciplines, such as anthropology, demography, ecology, economics, nutrition and political science. Focusing on the vast numbers of small, rural communities in the poorest regions of the world, the work has identified circumstances in which population growth, poverty and degradation of local resources often fuel one another. The collected research has shown that none of the three elements directly causes the other two; rather each influences, and is in turn influenced by, the others. This new perspective has significant implications for policies aimed at improving life for some of the world's most impoverished inhabitants.

In contrast with this new perspective, with its focus on local experience, popular tracts on the environment and population growth have usually taken a global view. They have emphasized the deleterious effects that a large population would have on our planet in the distant future. Although that slant has its uses, it has drawn attention away from the economic misery endemic today. Disaster is not something the poorest have to wait for: it is occurring even now. Besides, in developing countries, decisions on whether to have a child and on how to share education, food, work, health care and local resources are in large measure made within small entities such as households. So it makes sense to study the link between poverty, population growth and the environment from a myriad of local, even individual, viewpoints.

The household assumes various guises in different parts of the world. Some years ago Gary S. Becker of the University of Chicago was the first investigator to grapple with this difficulty. He used an idealized version of the concept to explore how choices made within a household would respond to changes in the outside world, such as employment opportunities and availability of credit, insurance, health care and education.

One problem with his method, as I saw it when I began my own work some

five years ago, was that it studied households in isolation; it did not investigate the dynamics between interacting units. In addition to understanding the forces that encouraged couples to favor large families, I wanted to understand the ways in which a reasoned decision to have children, made by each household, could end up being detrimental to all households.

In studying how such choices are made, I found a second problem with the early approach: by assuming that decision making was shared equally by adults, investigators had taken an altogether too benign view of the process. Control over a family's choices is, after all, often held unequally. If I wanted to understand how decisions were made, I would have to know who was doing the deciding.

Power and Gender

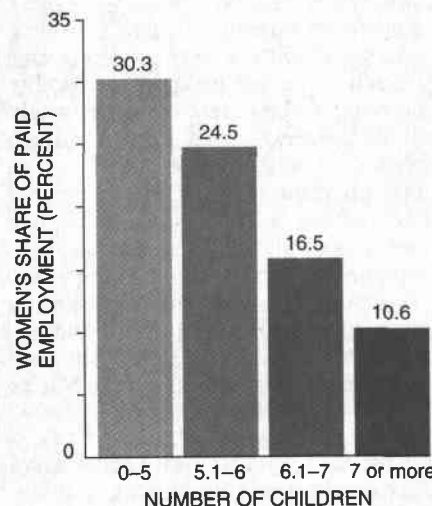
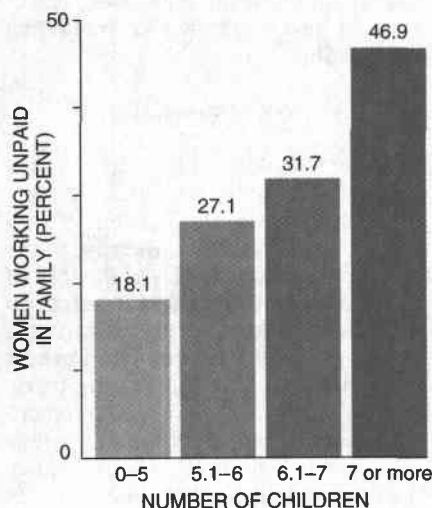
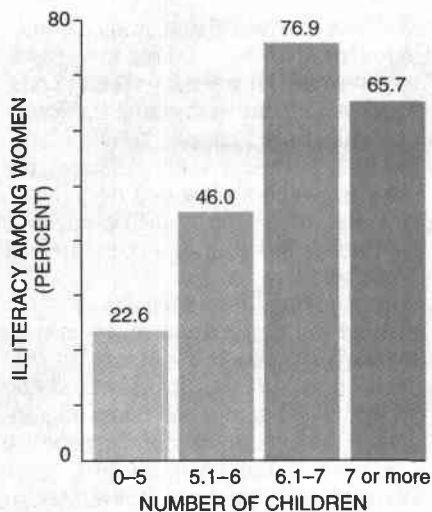
Those who enjoy the greatest power within a family can often be identified by the way the household's resources are divided. Judith Bruce of the Population Council, Mayra Buvinic of the International Center for Research on Women, Lincoln C. Chen and Amartya Sen of Harvard University and others have observed that the sharing of resources within a household is often unequal even when differences in needs are taken into account. In poor households in the Indian subcontinent, for example, men and boys usually get more sustenance than do women and girls, and the elderly get less than the young.

Such inequities prevail over fertility choices as well. Here also men wield more influence, even though women typically bear the greater cost. To grasp how great the burden can be, consider the number of live babies a woman would normally have if she managed to survive through her childbearing years. This number, called the total fertility rate, is between six and eight in sub-Saharan Africa. Each successful birth there involves at least a year and a half of



FETCHING WATER in Rajasthan, in the west of India, takes up several hours a day for each household. As resources become increasingly sparse and distant, additional hands become more valuable for such daily tasks, creating a demand for families to have more children. The burgeoning population puts more pressure on the environment, spurring a need for even more offspring in a cycle of increasing poverty, population and environmental damage.

PARTHA S. DASGUPTA, who was educated in Varanasi, Delhi and Cambridge, is Frank Ramsey Professor of Economics at the University of Cambridge and Fellow of St. John's College. He is also chairman of the Beijer International Institute of Ecological Economics of the Royal Swedish Academy of Sciences in Stockholm and Fellow of the British Academy. Dasgupta's research has ranged over various aspects of environmental, resource and population economics, most recently poverty and malnutrition.



pregnancy and breast-feeding. So in a society where female life expectancy at birth is 50 years and the fertility rate is, say, seven, nearly half of a woman's adult life is spent either carrying a child in her womb or breast-feeding it. And this calculation does not allow for unsuccessful pregnancies.

Another indicator of the price that women pay is maternal mortality. In most poor countries, complications related to pregnancy constitute the largest single cause of death of women in their reproductive years. In some parts of sub-Saharan Africa as many as one woman dies for every 50 live births. (The rate in Scandinavia today is one per 20,000.) At a total fertility rate of seven or more, the chance that a woman entering her reproductive years will not live through them is about one in six. Producing children therefore involves playing a kind of Russian roulette.

Given such a high cost of procreation, one expects that women, given a choice, would opt for fewer children. But are birth rates in fact highest in societies where women have the least power within the family? Data on the status of women from 79 so-called Third World countries display an unmistakable pattern: high fertility, high rates of illiteracy, low share of paid employment and a high percentage working at home for no pay—they all hang together. From the statistics alone it is difficult to discern which of these factors are causing, and which are merely correlated with, high fertility. But the findings are consistent with the possibility that lack of paid employment and education limits a woman's ability to make decisions and therefore promotes population growth.

There is also good reason to think that lack of income-generating employment reduces women's power more directly than does lack of education. Such an insight has implications for policy. It is all well and good, for example, to urge governments in poor countries to invest in literacy programs. But the results could be disappointing. Many factors militate against poor households' taking advantage of subsidized education. If children are needed to work inside and outside the home, then keeping them in school (even a cheap one) is costly. In patrilineal societies, educated girls can also be perceived as less pliable and harder to marry off. Indeed, the benefits of subsidies to even primary education are reaped disproportionately by families that are better off.

In contrast, policies aimed at increasing women's productivity at home and improving their earnings in the marketplace would directly empower them, especially within the family. Greater earn-

ing power for women would also raise for men the implicit costs of procreation (which keeps women from bringing in cash income). This is not to deny the value of public investment in primary and secondary education in developing countries. It is only to say we should be wary of claims that such investment is a panacea for the population problem.

The importance of gender inequality to overpopulation in poor nations is fortunately gaining international recognition. Indeed, the United Nations Conference on Population and Development held in Cairo in September 1994 emphasized women's reproductive rights and the means by which they could be protected and promoted. But there is more to the population problem than gender inequalities. Even when both parents participate in the decision to have a child, there are several pathways through which the choice becomes harmful to the community. These routes have been uncovered by inquiring into the various motives for procreation.

Little Hands Help...

One motive, common to humankind, relates to children as ends in themselves. It ranges from the desire to have children because they are playful and enjoyable, to the desire to obey the dictates of tradition and religion. One such injunction emanates from the cult of the ancestor, which, taking religion to be the act of reproducing the lineage, requires women to bear many children [see "High Fertility in Sub-Saharan Africa," by John C. Caldwell and Pat Caldwell; *SCIENTIFIC AMERICAN*, May 1990].

Such traditions are often perpetuated by imitative behavior. Procreation in closely knit communities is not only a private matter; it is also a social activity, influenced by the cultural milieu. Often there are norms encouraging high fertility rates that no household desires unilaterally to break. (These norms may well have outlasted any rationale they had in the past.) Consequently, so long as all others aim at large families, no household on its own will wish to deviate. Thus, a society can get stuck at a self-sustaining mode of behavior that is characterized by high fertility and low educational attainment.

This does not mean that society will live with it forever. As always, people differ in the extent to which they adhere to tradition. Inevitably some, for one reason or another, will experiment, take risks and refrain from joining the crowd. They are the nonconformists, and they help to lead the way. An increase in female literacy could well trigger such a process.

TOTAL FERTILITY RATE around the world (the average number of children a woman produces) generally increases with the percentage of women in a country who are illiterate (*top*) or work unpaid in the family (*middle*). Fertility decreases when a larger share of the paid employment belongs to women (*bottom*). Bringing in a cash income may empower a woman in making decisions within her family, allowing her to resist pressure to bear more children.

LISA BURNETT

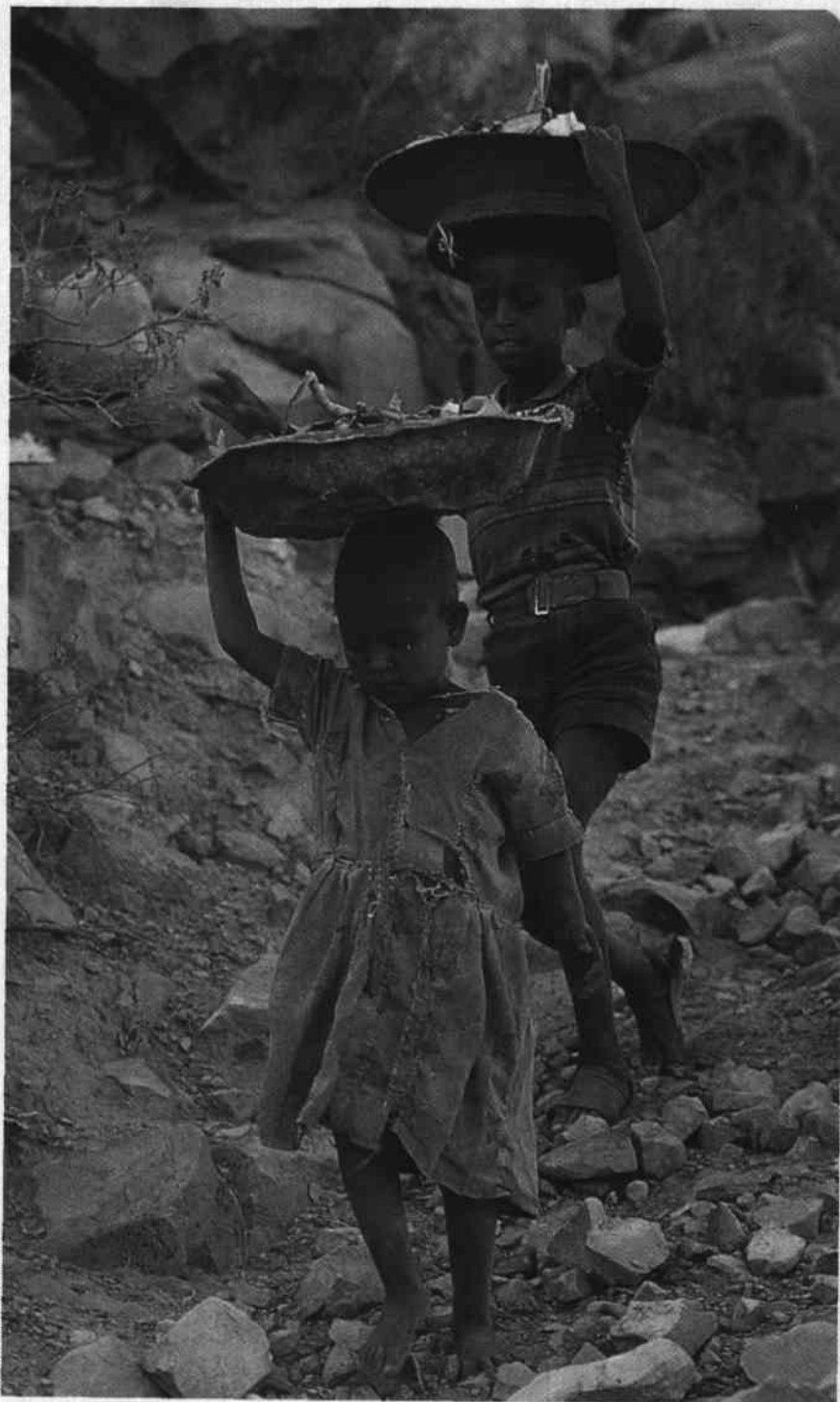
Still other motives for procreation involve viewing children as productive assets. In a rural economy where avenues for saving are highly restricted, parents value children as a source of security in their old age. Mead Cain, previously at the Population Council, studied this aspect extensively. Less discussed, at least until recently, is another kind of motivation, explored by John C. Caldwell of the Australian National University, Marc L. Nerlove of the University of Maryland and Anke S. Meyer of the World Bank and by Karl-Göran Mäler of the Beijer International Institute of Ecological Economics in Stockholm and me. It stems from children's being valuable to their parents not only for future income but also as a source of current income.

Third World countries are, for the most part, subsistence economies. The rural folk eke out a living by using products gleaned directly from plants and animals. Much labor is needed even for simple tasks. In addition, poor rural households do not have access to modern sources of domestic energy or tap water. In semiarid and arid regions the water supply may not even be nearby. Nor is fuelwood at hand when the forests recede. In addition to cultivating crops, caring for livestock, cooking food and producing simple marketable products, members of a household may have to spend as much as five to six hours a day fetching water and collecting fodder and wood.

Children, then, are needed as workers even when their parents are in their prime. Small households are simply not viable; each one needs many hands. In parts of India, children between 10 and 15 years have been observed to work as much as one and a half times the number of hours that adult males do. By the age of six, children in rural India tend domestic animals and care for younger siblings, fetch water and collect firewood, dung and fodder. It may well be that the usefulness of each extra hand increases with declining availability of resources, as measured by, say, the distance to sources of fuel and water.

...But at a Hidden Cost

The need for many hands can lead to a destructive situation, especially when parents do not have to pay the full price of rearing their children but share those costs with the community. In recent years, mores that once regulated the use of local resources have changed. Since time immemorial, rural assets such as village ponds and water holes, threshing grounds, grazing fields, and local forests have been owned communally. This form of control enabled



COLLECTING FIREWOOD is one way a brother and sister in Eritrea contribute needed labor to a family. Households throughout much of the Third World count on youngsters for a variety of tasks, such as herding cows and goats, looking after younger siblings, carrying water and searching for fuel and fodder. Older children often work as much as one and a half times the number of hours as men. Many are sold into "bonded labor," where they work to repay parents' debts.

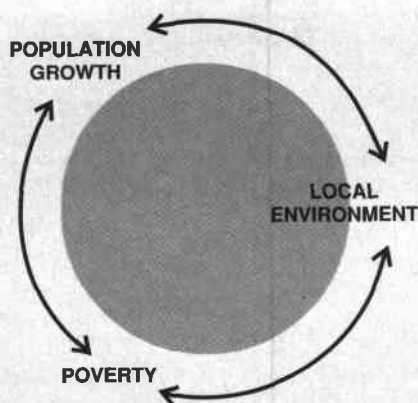
households in semiarid regions to pool their risks. Elinor Ostrom of Indiana University and others have shown that communities have protected such local commons against overexploitation by invoking norms, imposing fines for deviant behavior and so forth.

But the very process of economic development can erode traditional methods of control. Increased urbanization and mobility can do so as well. Social rules are also endangered by civil strife and by the takeover of resources by landowners or the state. As norms de-

grade, parents pass some of the costs of children on to the community by over-exploiting the commons. If access to shared resources continues, parents produce too many children, which leads to greater crowding and susceptibility to disease as well as to more pressure on environmental resources. But no household, on its own, takes into account the harm it inflicts on others when bringing forth another child.

Parental costs of procreation are also lower when relatives provide a helping hand. Although the price of carrying a child is paid by the mother, the cost of rearing the child is often shared among the kinship. Caroline H. Bledsoe of Northwestern University and others have observed that in much of sub-Saharan Africa fosterage is commonplace, affording a form of insurance protection in semiarid regions. In parts of West Africa about a third of the children have been found to be living with their kin at any given time. Nephews and nieces have the same rights of accommodation and support as do biological offspring. In recent work I have shown that this arrangement encourages couples to have too many offspring if the parents' share of the benefits from having children exceeds their share of the costs.

In addition, where conjugal bonds are weak, as they are in sub-Saharan Africa, fathers often do not bear the costs of siring a child. Historical demographers, such as E. A. Wrigley of the University of Cambridge, have noted a significant difference between western Europe in the 18th century and modern preindustrial societies. In the former, marriage normally meant establishing a new household. This requirement led to late marriages; it also meant that parents bore the cost of rearing their children. Indeed, fertility rates in France dropped



REGION	TOTAL FERTILITY RATE
SUB-SAHARAN AFRICA	6 TO 8
INDIA	4
CHINA	2.3
JAPAN AND WESTERN INDUSTRIAL DEMOCRACIES	1.5 TO 1.9

POVERTY, population growth and environmental degradation interact in a cyclic pattern (top). The chart (bottom) shows that fertility is higher in countries that are poorer.

before mortality rates registered a decline, before modern family-planning techniques became available and before women became literate.

The perception of both the low costs and high benefits of procreation induces households to produce too many children. In certain circumstances a disastrous process can begin. As the community's resources are depleted, more hands are needed to gather fuel and water for daily use. More children are then produced, further damaging the

local environment and in turn providing the household with an incentive to enlarge. When this happens, fertility and environmental degradation reinforce each other in an escalating spiral. By the time some countervailing set of factors—whether public policy or diminished benefits from having additional children—stops the spiral, millions of lives may have suffered through worsening poverty.

Recent findings by the World Bank on sub-Saharan Africa have revealed positive correlations among poverty, fertility and deterioration of the local environment. Such data cannot reveal causal connections, but they do support the idea of a positive-feedback process such as I have described. Over time, the effect of this spiral can be large, as manifested by battles for resources [see "Environmental Change and Violent Conflict," by T. F. Homer-Dixon, J. H. Boutwell and G. W. Rathjens; *SCIENTIFIC AMERICAN*, February 1993].

The victims hit hardest among those who survive are society's outcasts—the migrants and the dispossessed, some of whom in the course of time become the emaciated beggars seen on the streets of large towns and cities in underdeveloped countries. Historical studies by Robert W. Fogel of the University of Chicago and theoretical explorations by Debraj Ray of Boston University and me, when taken together, show that the spiral I have outlined here is one way in which destitutes are created. Emaciated beggars are not lazy; they have to husband their precarious hold on energy. Having suffered from malnutrition, they cease to be marketable.

Families with greater access to resources are, however, in a position to limit their size and propel themselves into still higher income levels. It is my

Green Net National Production

Some economists believe population growth is conducive to economic growth. They cite statistics showing that, except in sub-Saharan Africa, food production and gross income per head have generally grown since the end of World War II. Even in poor regions, infant survival rate, literacy and life expectancy have improved, despite the population's having grown much faster than in the past.

One weakness of this argument is that it is based on statistics that ignore the depletion of the environmental resource base, on which all production ultimately depends. This base includes soil and its cover, freshwater, breathable air, fisheries and forests. No doubt it is tempting to infer from past trends that human ingenuity can be relied on to overcome the stresses that growing populations impose on the natural environment.

Yet that is not likely to be the case. Societies already use

an enormous 40 percent of the net energy created by terrestrial photosynthesis. Geoffrey M. Heal of Columbia University, John M. Hartwick of Queens University and Karl-Cöran Mäler of the Beijer International Institute of Ecological Economics in Stockholm and I have shown how to include environmental degradation in estimating the net national product, or NNP. NNP is obtained by deducting from gross national product the value of, for example, coal extracted or timber logged.

This "green NNP" captures not only present production but also the possibility of future production brought about by resources we bequeath. Viewed through NNP, the future appears far less rosy. Indeed, I know of no ecologist who thinks a population of 11 billion (projected for the year 2050) can support itself at a material standard of living of, say, today's representative American.

impression that among the urban middle classes in northern India, the transition to a lower fertility rate has already been achieved. India provides an example of how the vicious cycle I have described can enable extreme poverty to persist amid a growth in well-being in the rest of society. The Matthew effect—"Unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath"—works relentlessly in impoverished countries.

Breaking Free

This analysis suggests that the way to reduce fertility is to break the destructive spiral. Parental demand for children rather than an unmet need for contraceptives in large measure explains reproductive behavior in developing countries. We should therefore try to identify policies that will change the options available to men and women so that couples choose to limit the number of offspring they produce.

In this regard, civil liberties, as opposed to coercion, play a particular role. Some years ago my colleague Martin R. Weale and I showed through statistical analysis that even in poor countries political and civil liberties go together with improvements in other aspects of life, such as income per person, life expectancy at birth and infant survival rate. Thus, there are now reasons for thinking that such liberties are not only desirable in themselves but also empower people to flourish economically. Recently Adam Przeworski of the University of Chicago demonstrated that fertility, as well, is lower in countries where citizens enjoy more civil and political freedom. (An exception is China, which represents only one country out of many in this analysis.)

The most potent solution in semiarid regions of sub-Saharan Africa and the Indian subcontinent is to deploy a number of policies simultaneously. Family-planning services, especially when allied with health services, and measures that empower women are certainly helpful. As societal norms break down and traditional support systems falter, those women who choose to change their behavior become financially and socially more vulnerable. So a literacy and employment drive for women is essential to smooth the transition to having fewer children.

But improving social coordination and directly increasing the economic security of the poor are also essential. Providing cheap fuel and potable water will reduce the usefulness of extra hands. When a child becomes perceived as ex-



DESTITUTES sleep in the Indian city of Bombay, having migrated from villages where spiraling poverty, population and environmental decay have made life impossible. In time, some of these dispossessed become the emaciated beggars and laborers common to urban areas in the Third World.

pensive, we may finally have a hope of dislodging the rapacious hold of high fertility rates.

Each of the prescriptions suggested by our new perspective on the links between population, poverty and environ-

mental degradation is desirable by itself, not just when we have those problems in mind. It seems to me that this consonance of means and ends is a most agreeable fact in what is otherwise a depressing field of study.

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Sonoluminescence: Sound into Light

*A bubble of air can focus acoustic energy
a trillionfold to produce picosecond flashes of light.
The mechanism eludes complete explanation*

by Seth J. Putterman

Imagine you are riding a roller coaster. First, you chug up a long incline slowly. When you get to the top, your car free-falls, speeding up until it reaches the bottom of the drop, where the deceleration crams you into your

seat. That sensation is what you would feel if you were riding a pulsating bubble of air trapped in water—except that the drop would reach supersonic speeds and at the bottom you would be crushed into your seat with a force

equal to 1,000 billion times your weight.

Obviously, more than your stomach would react to such a ride. As for the bubble, it responds to the extraordinary force by creating a flash of light only a tiny fraction of a second long. The light

